CONTRACT: NAS 8-11811

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October 1964

DESIGN, DEVELOPMENT, MANUFACTURE, AND DELIVER NEW CONCEPTS FOR HIGH ENERGY RATE FORMING SYSTEM

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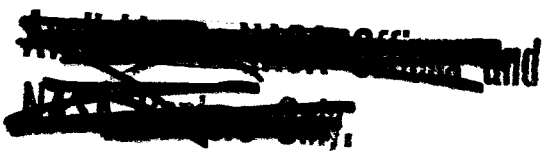
Republic Aviation Corporation
Manufacturing Research Department

RAC 2647

The E. B. W. with magnetic assist, and the electromagnetic transducer were tested for directional waves in liquid for metal forming. The magnetic assist up to 5 KV was insignificant.

The electromagnetic transducer was effective but design modifications are required.



Republic Aviation Corporation
Farmingdale, New York

Design, Development, Manufacture, and Deliver New Concepts for High Energy Rate Forming System

Contract No. NAS 8-11811
Quarterly Report No. 1

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ILLUSTRATIONS

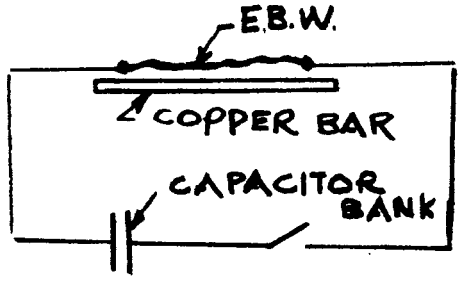
Status of Work as of September 30, 1964

During the first three months of this contract, attempts were made to prove the principle of two different methods of wave generation. The design of the devices and the results of the tests are given in the following pages.

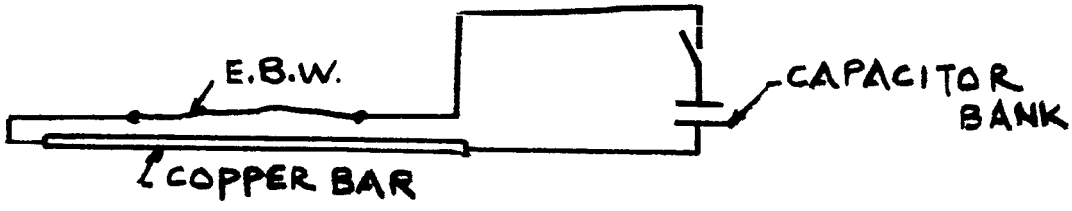
The design of the devices was rudimentary: in the final choice, however all the related aspects will be considered and the device shall be optimized for efficiency and handling.

1.0 E. B. W. wave generator

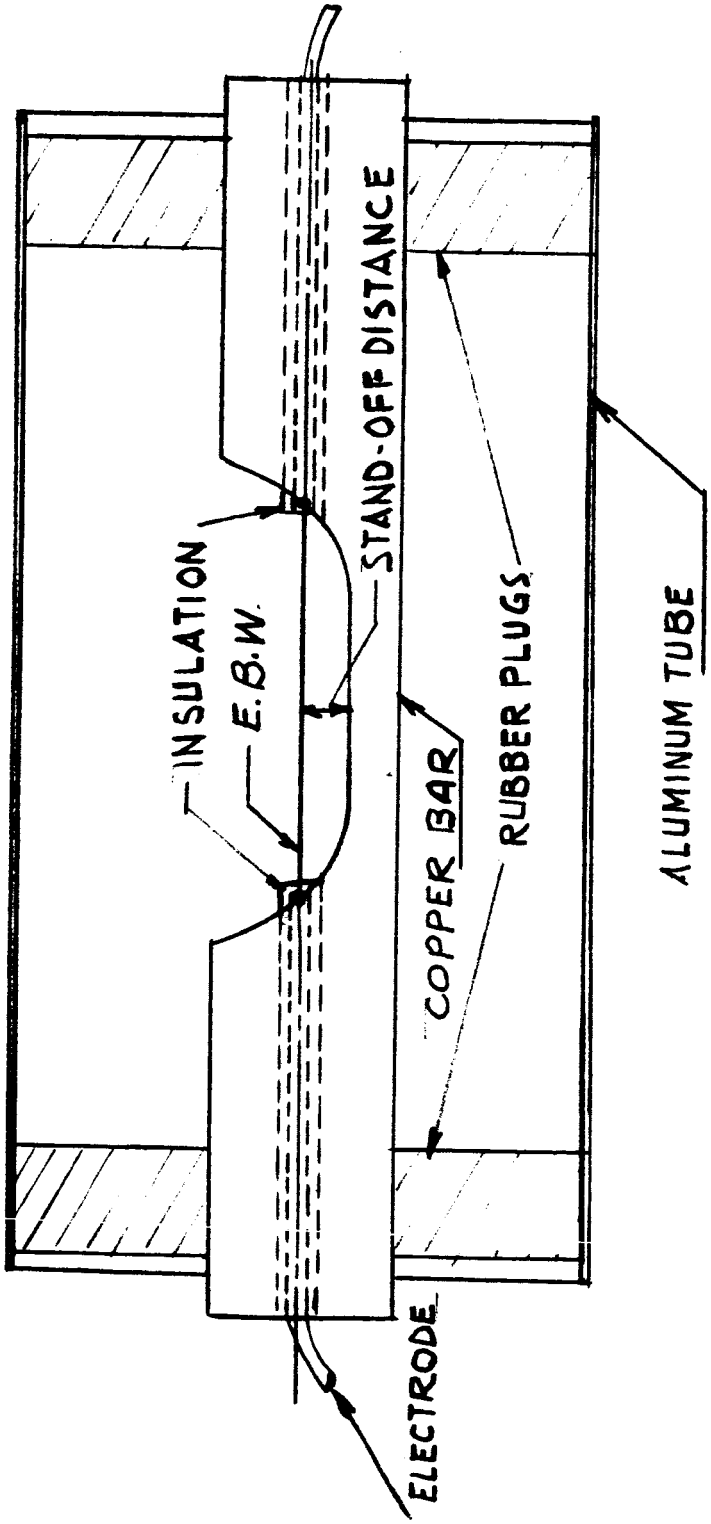
In the first device, a spark discharge was used in front of a copper back-up plate. The tests were carried out to show the extent to which the work available in the discharge could be directed by the magnetic coupling of the E. B. W. with the current carrying back-up plate.



E.B.W WITH REFLECTOR.



E.B.W. WITH REFLECTOR CONDUCTOR.



E.B.W. WAVE GENERATOR

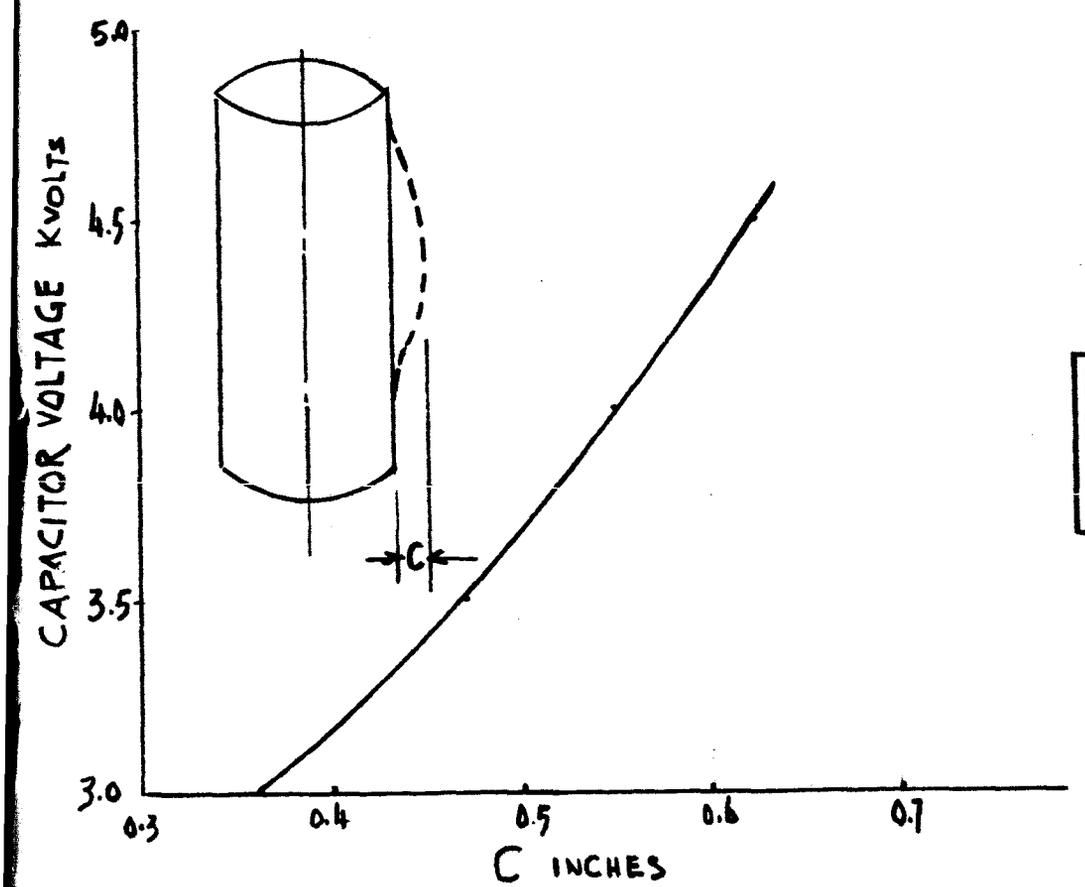
A 1.5 diameter copper bar was recessed, as shown in the schematic, to provide 1/4" clearance with a 0.06" diameter aluminum wire inserted through a hole in the center of the copper bar.

An aluminum tube 3" diameter, 1/16" thick was placed over the assembly and the ends were plugged with rubber. The space between was filled with water. Two aspects of the setup were investigated:

a) The copper bar was made as one of the electrodes; this was done to show the magnetic assist, if any, by the magnetic coupling of the copper conductor with the exploding wire.

b) The copper bar was not a current carrying conductor, but was considered as a wave reflector.

The results are shown in the graph below. (See also Figures 3 and 4)



E.B.W. WAVE GENERATOR

RESULTS

IDENTICAL FOR BOTH THE REFLECTOR AND REFLECTOR-CONDUCTOR METHODS.

The results shown in the previous page indicate that a) the device can provide a method of wave generation and b) the resultant directionality was due to wave reflection from the copper surface. There was no apparent difference between the case of the copper-as-reflector and the case of the copper-as-reflector-conductor.

The current traces for the reflector and the reflector-conductor case are shown in Figures 1 and 2. It is shown that both the total time of discharge as well as the time interval during which the E. B. W. was conducting, change with the capacitor voltage (i. e. the E. B. W. conducting interval is represented in the current traces by the horizontal distance from the start point of the trace to the cutoff point).

In the reflector case the cut-off time is longer, indicating a slower exploding process; the current levels however are almost identical.

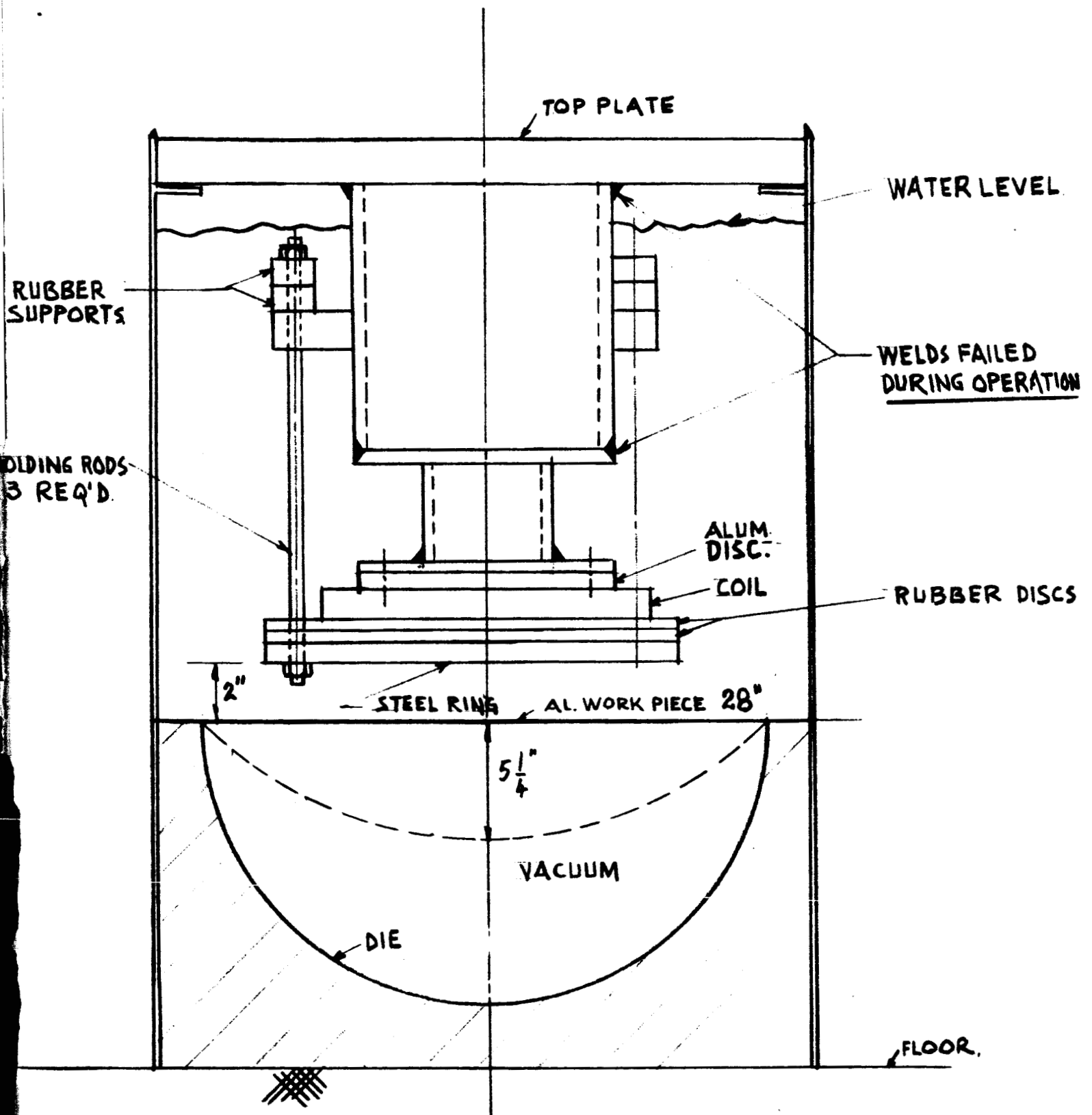
In addition, tests were performed with a 0. 03 aluminum wire. The results were inconsistent and the method unreliable. The reason was the small cross sectional area of the wire; current found paths of less resistance and spark marks were observed on the copper bar after the test. A radial distance of 1/8 inch between the E. B. W. and the copper bar was also tried, but sparking between the E. B. W. terminals and the copper bar made the results also unreliable. From these tests, it was concluded that the expected magnetic assist in the reflector-conductor case was insignificant up to 5 KV capacitor voltage.

2. 0 Electromagnetic Transducer Wave Generator

The principle of an electromagnetic transducer was used to accelerate a disc and thereby generate a wave. (See Figures 4, 5 and schematic on next page).

It was shown in the proposal (RAC 2419) that a pancake coil in intimate contact with an aluminum disc can be used to accelerate the disc during the discharge of 50, 000 joules, thereby forming a 28" dome through a compression wave.

It was thus decided to investigate this possibility further first by making the aluminum disc stationary and the coil moveable and then the coil stationary and the aluminum disc moveable. The reason for the two types of tests was



ELECTRO-MAGNETIC WAVE GENERATOR
SCHEMATIC

mainly to investigate the effects of the stress waves in the supporting structure.

In the tests discussed in this report, only the first case was investigated.

A 12 inch diameter coil was imbedded in micarta and secured with fiberglass and epoxy. It was then inserted between an aluminum disc and rubber discs. The aluminum disc was bolted to a massive column weighing over 1000 lbs. The rubber discs were cemented to a steel ring which was suspended from the column through rubber supports. The coil was connected to the capacitor bank through flexible braided wire insulated from the steel column, but not sealed from the water in which the device is immersed during operation.

The device was inserted in a water tank over the die (see schematic). As the capacitor bank discharged through the coil, the magnetic pressure between the aluminum plate and the coil caused the coil toaccelerate thus generating a pressure wave in the water. The coil, however, was not entirely free since it was resting on the rubber discs, thus it was doing work compressing the rubber discs and the rubber supports.

As the pressure wave encountered the workpiece, it reflected, causing the workpiece to accelerate. The work piece then deformed until its strength checked its motion.

The device was used with the 28" diameter workpiece in order to compare its efficiency with the 28 inch diameter domes formed with the E. B. W. principle under similar conditions.

The tests proceeded satisfactorily from 3000 to 17,000 joules in steps of 2000 joules with 10 discharges at each energy level. (See Figure 8) The results showed that a) the wave was forming the workpiece and b) although the rate of forming per shot was much less than the E. B. W. at equivalent voltage settings, it was possible to discharge the capacitor bank every 15 seconds so that the overall forming rate was about equal to E. B. W.

The braided wire broke off 3 times at its joint with the coil, but no other difficulties appeared until it was observed that the welded joints were breaking off as shown in the schematic.

The workpiece was formed to a depth of 5 1/4" at this point. See Figure 7.

The cause of the weld failure was due to the pressure wave transmitted through the column. It indicates that a free column rested, but not attached to the top plate would be prefereable. Such a design will also provide an adjustable stand off distance and allow the coil to be lowered and kept near the workpiece.

Two typical current traces are shown in Figure 6 The dip shown in one of the figures indicates extraneous sparking due to the snapping of one of the coil terminals.

Anticipated work - October 1 to December 30

A new electromagnetic transducer wave generator will be designed and tests on the 28" workpiece will continue.

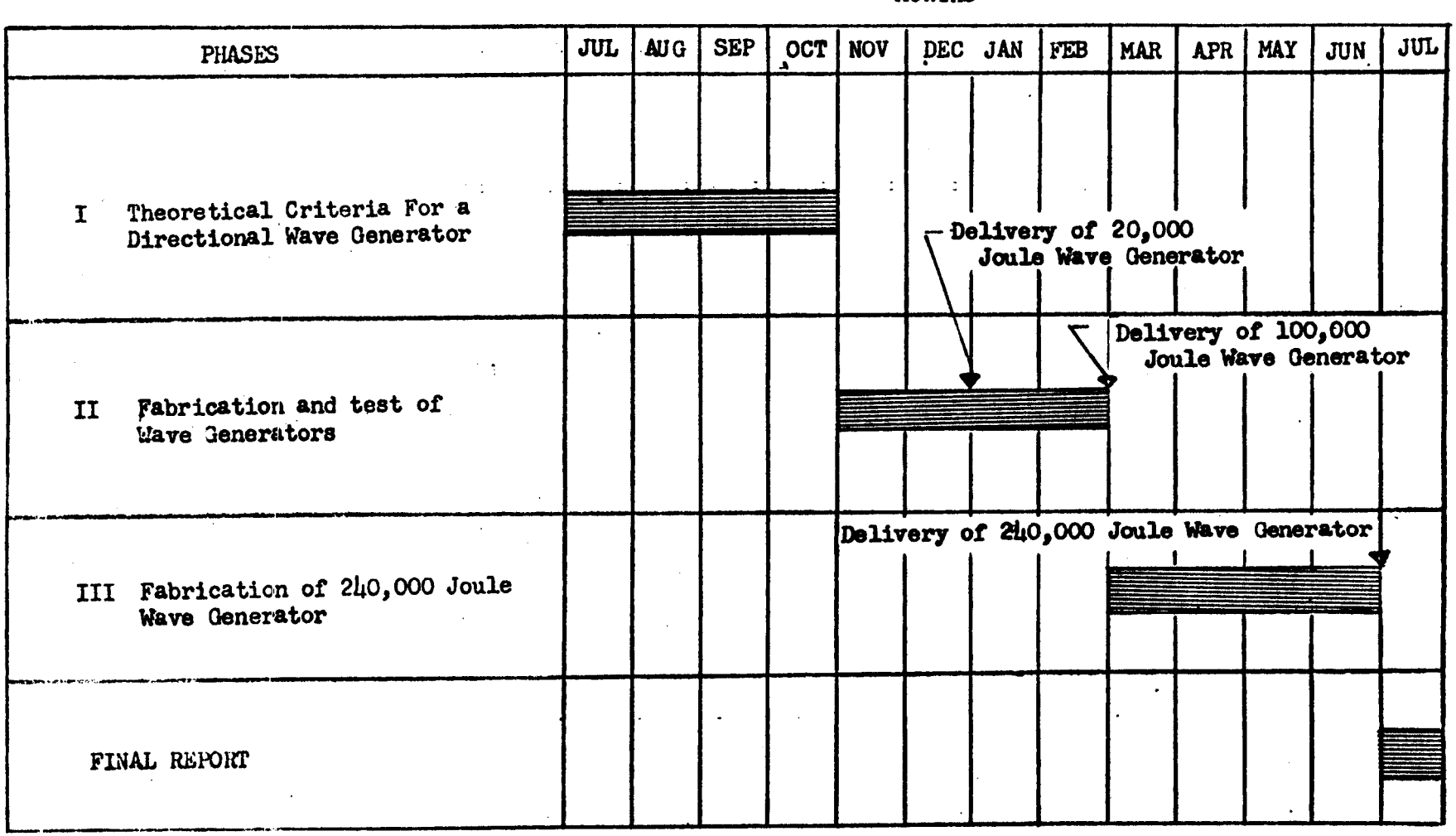
In the new design, the coil will be stationary and the aluminum plate free to move. Furthermore, the back up column of the coil will be a damping device, free to move upwards. The aluminum plate on the other hand, which will generate the compression wave will be guided along a tube. This setup is expected to increase the wave directionality and avoid side dissipations. A pressure transducer will be used at the wall of the tube to record the pressure time profile. This will be necessary for evaluating the efficiency of wave generation. Current traces of the capacitor bank discharges will be taken in every discharge. The current traces, together with other electrical characteristics of the coils and capacitor banks will then be evaluated and related to the amplitude and time duration of the generated compression wave. The work done on the workpiece will then be evaluated from the wave characteristics.

At this stage of the program, the electromagnetic transducer wave generator is expected to be the final choice. Thus the work will be directed toward final optimization and fabrication of the device.

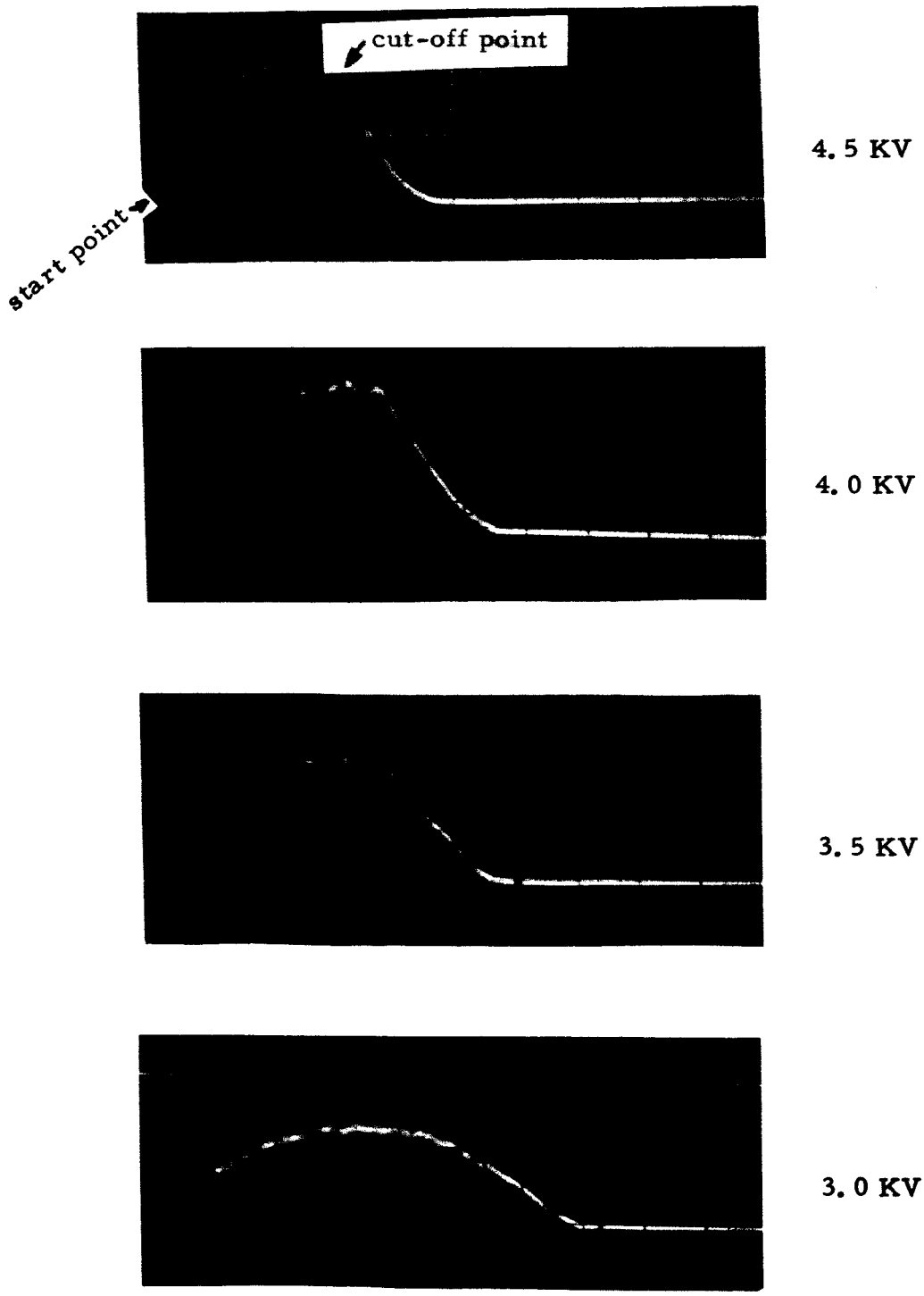
The manhours expended during the first three months are as follows:

Engineering	246	(remaining 1054)
Shop	289	(remaining 1986)

The program planning chart is shown in the next page; it remains unchanged.



PROGRAM PLANNING CHART

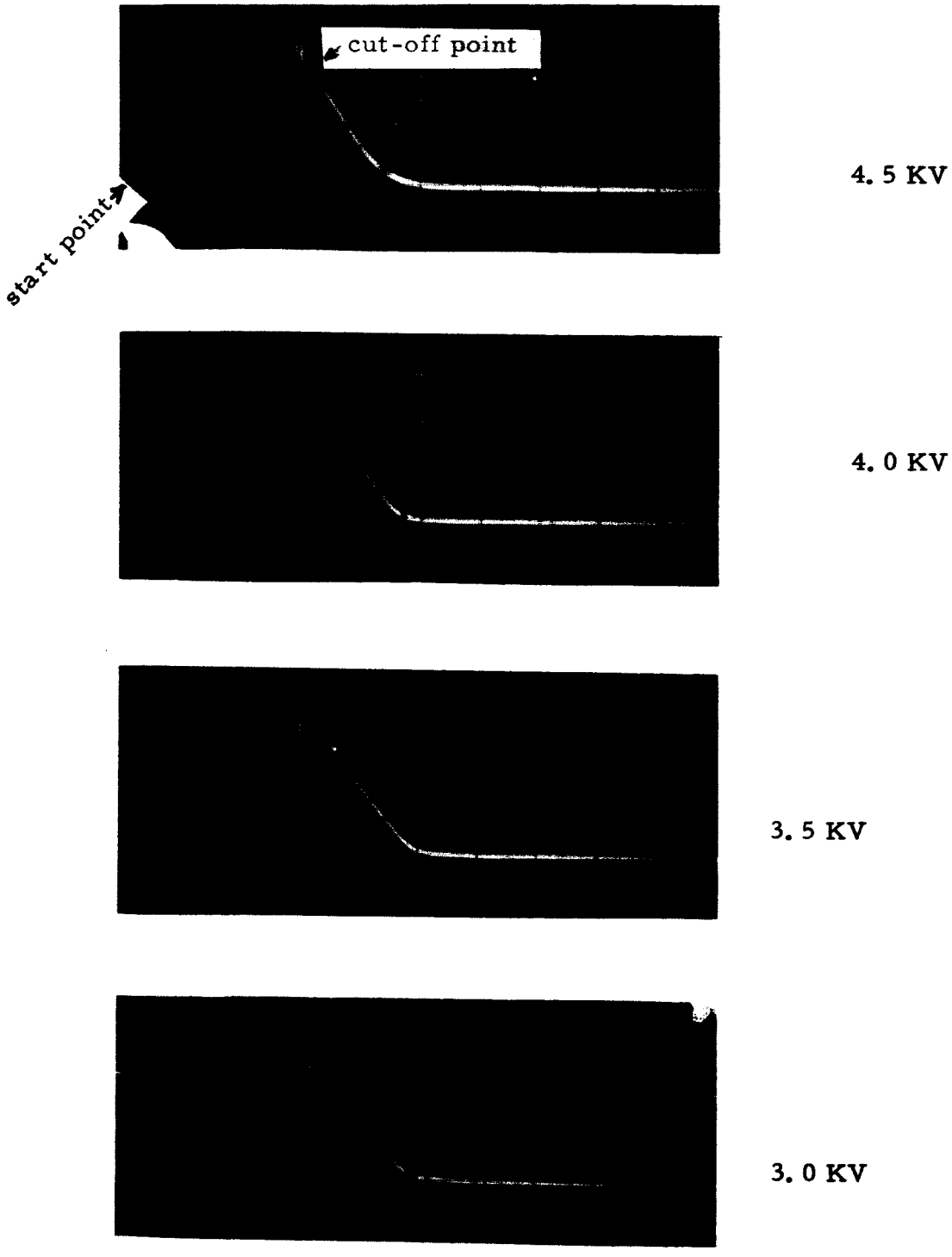


Reflector Case Current Traces Capacitor Bank: 960 uf

1 Volt/cm Vertical 25, 160 amperes/volt 20 u sec/cm Horizontal

CURRENT TRACES OF E. B. W. WITH REFLECTOR

FIGURE 1



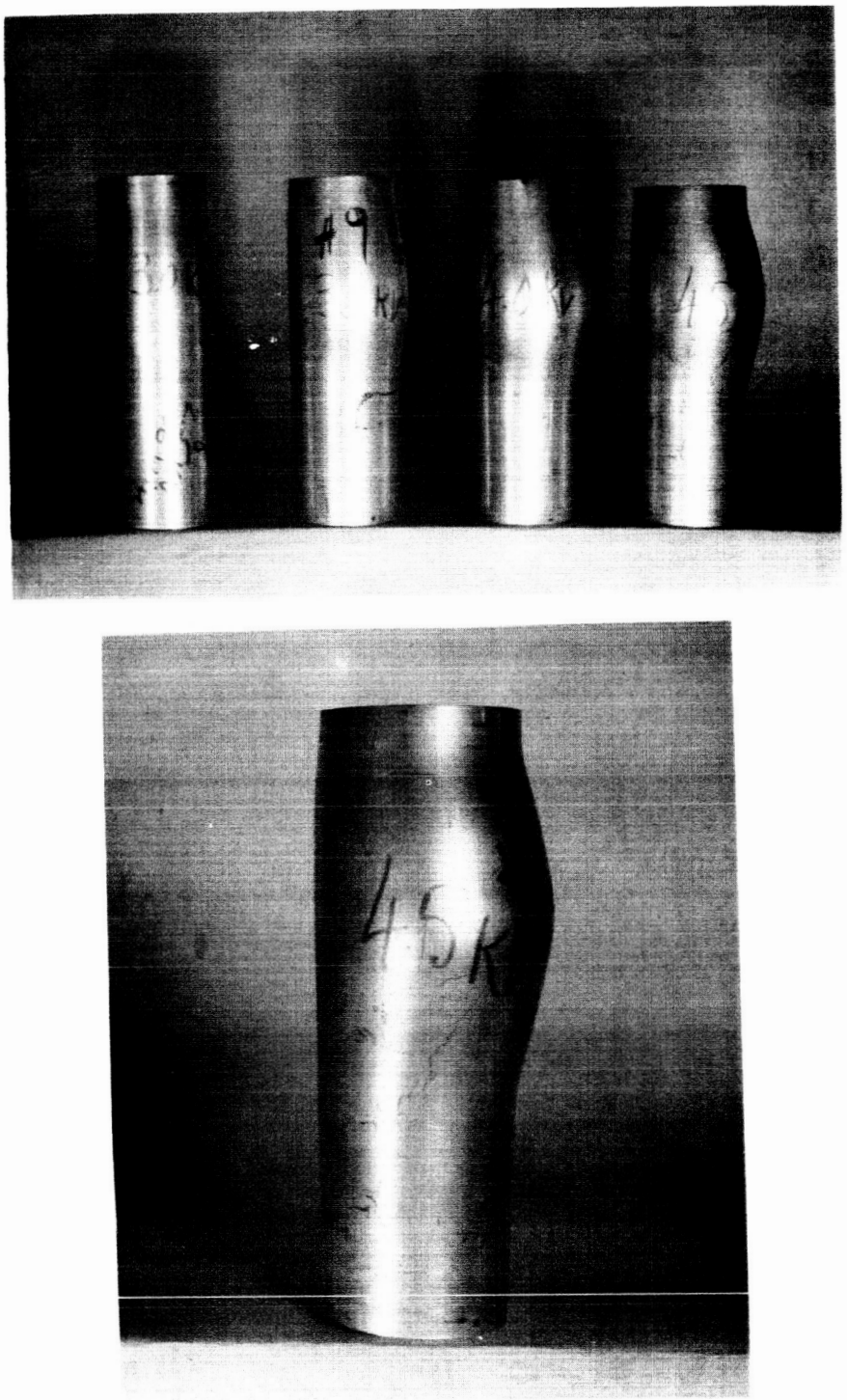
Reflector-Conductor Case Current Traces

Capacitor Bank: 960 uf 1 Volt/cm Vertical 25, 160 ampere/volt

20 u sec/cm Horizontal

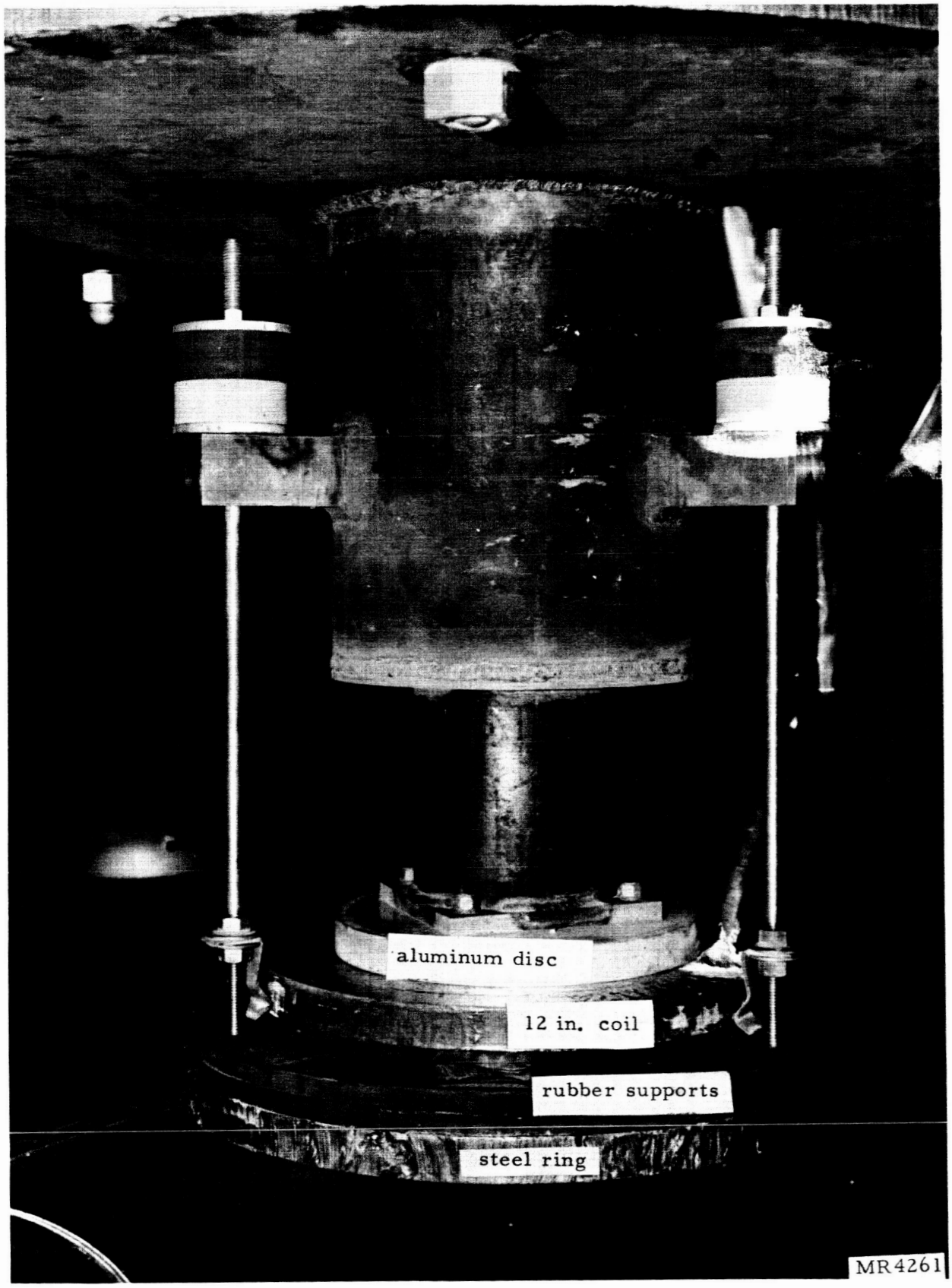
CURRENT TRACES OF E. B. W. WITH REFLECTOR-CONDUCTOR

FIGURE 2



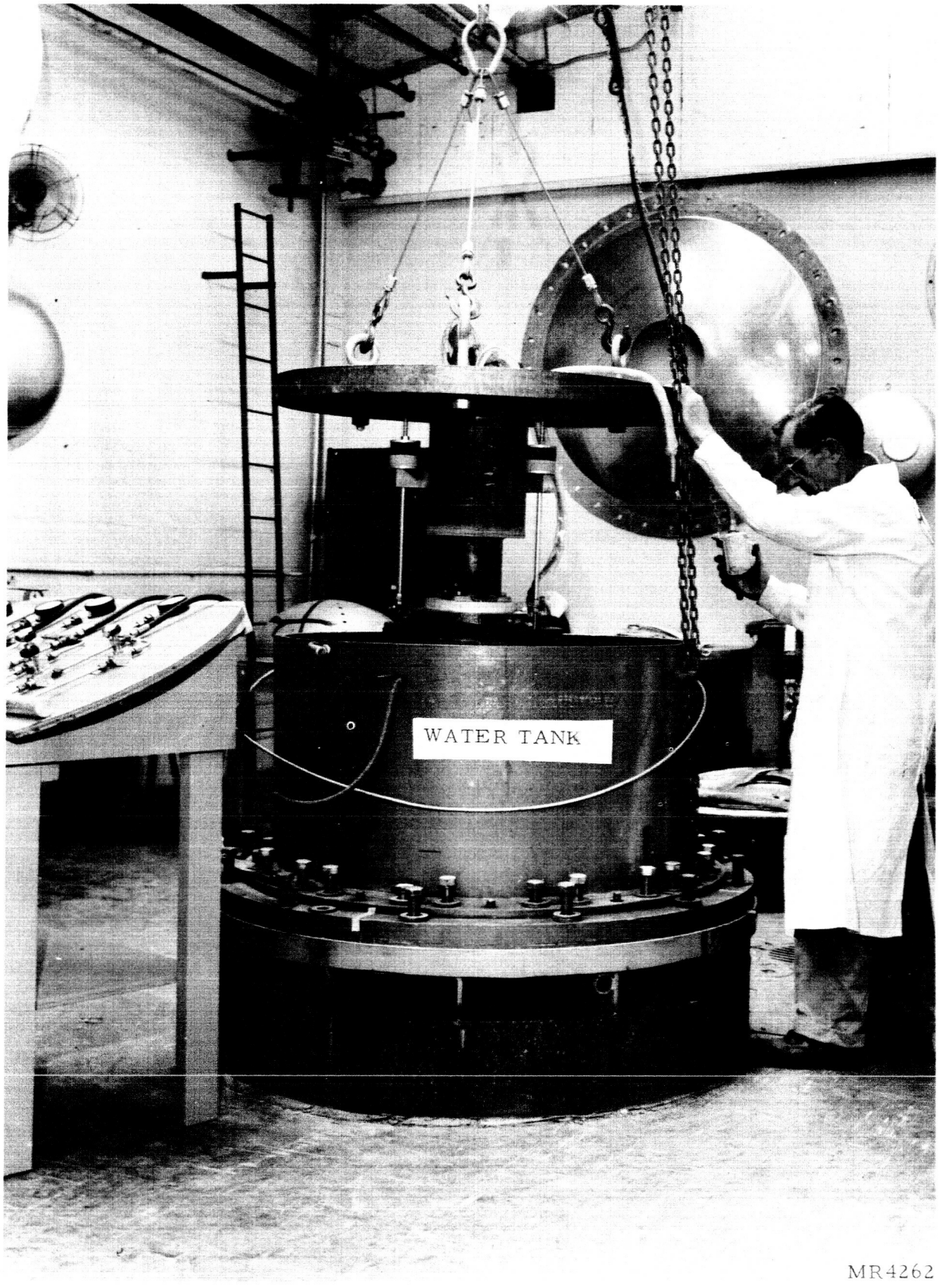
TUBES FORMED BY THE E. B. W. WITH REFLECTOR

FIGURE 3



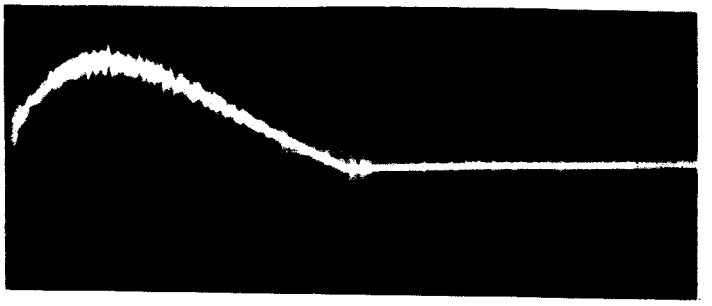
ELECTROMAGNETIC TRANSDUCER, WAVE GENERATOR

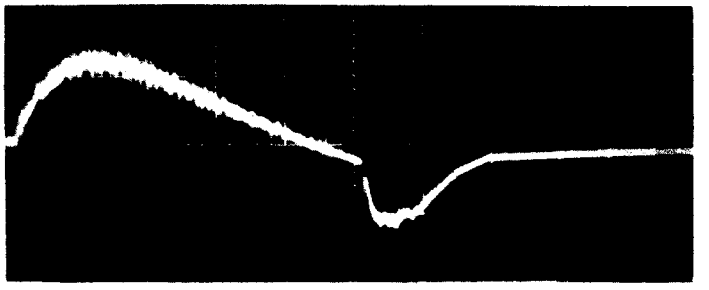
FIGURE 4



TRANSDUCER, WATER TANK AND 28 INCH DIE

FIGURE 5

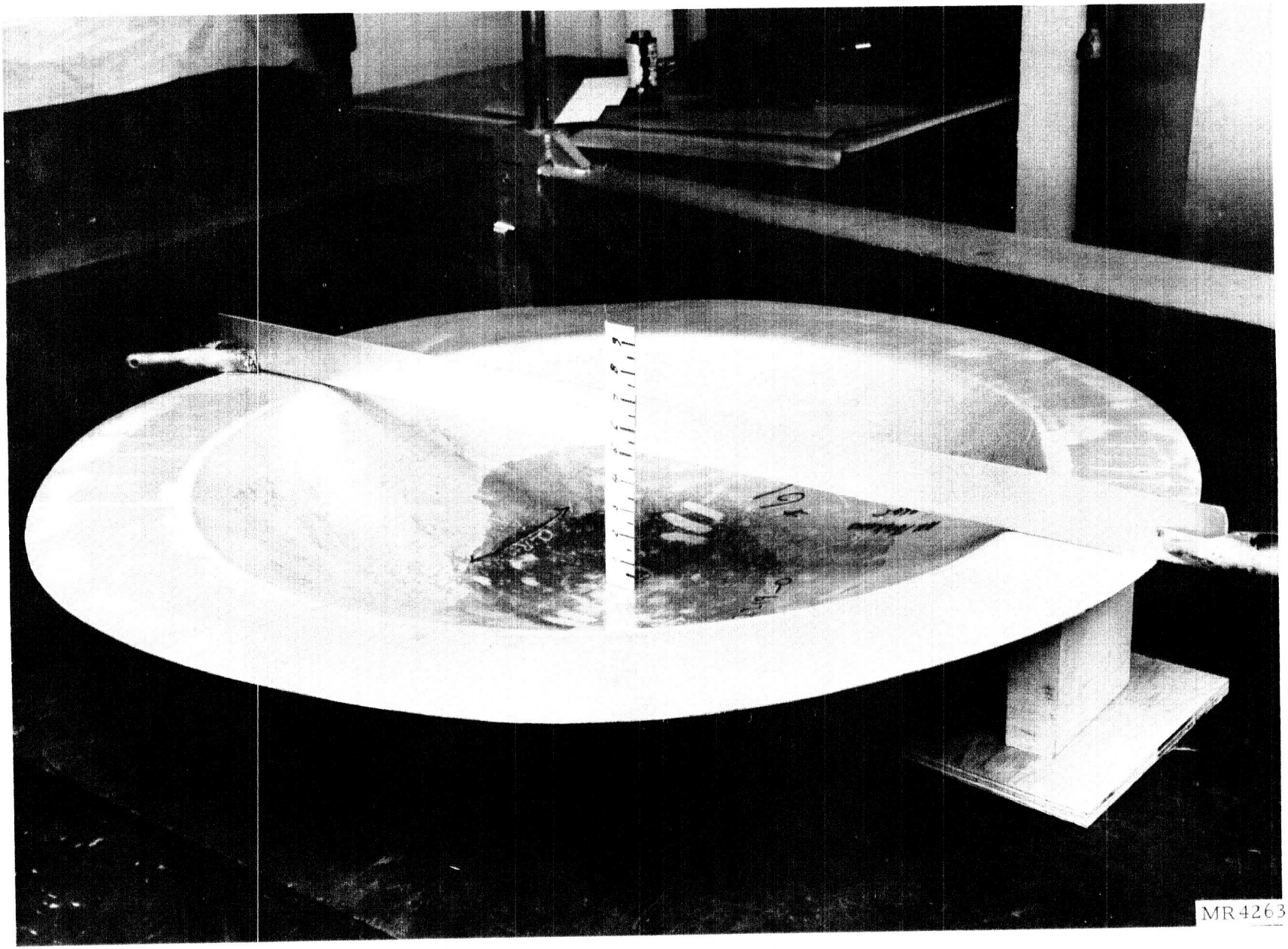




5.8 KV
960 uf
0.5 V/cm Vertical
25,160 amperes/volt
0.2 m sec/cm

ELECTROMAGNETIC TRANSDUCER, WAVE GENERATOR
CURRENT TRACES

FIGURE 6



28" DOME, FORMED BY WAVE GENERATOR

FIGURE 7

.064" 2219-0 40" Diameter Blank
4 piece bladder
29" Hg Vac.
28" Diameter Epoxy Die
960 ufds Capacitor Bank
12" - 40 turn flat spiral coil

Total Depth (in.)	Δ Depth (in.)	Shot No.	KV	Average Pressure	Bladder* Pressure 3	6	9	12	Remarks
1.81	1.81	-	-	75	75	75	75	75	Depth due to vacuum alone
1.83	0.02	-	-	"	"	"	"	"	Depth due to weight of water
1.83	0	1-10	1.5	100	100	100	100	100	Energy too low-no movement
1.93	0.10	11-20	2.1	"	"	"	"	")	See Note (1)
2.20	0.27	21-30	2.9	"	"	"	"	")	
2.78	0.58	31-34	4.1	"	"	"	"	"	See Note (2)
2.82	0.04	35-37	4.1	"	"	"	"	"	See Note (3)
2.82	0	38-43	4.1	"	"	"	"	"	Spot weld failure
3.02	0.20	44-46	4.1	"	"	"	"	"	
3.27	0.25	47-56	4.1	"	"	"	"	"	
3.52	0.25	57-61	4.55	"	"	"	"	"	
3.85	0.33	62-71	4.55	"	"	"	"	"	
4.23	0.38	72-91	4.9	300	300	300	300	300	
4.51	0.28	92-101	5.4	200	100	200	300	200	
4.70	0.19	102-111	5.6	"	"	"	"	"	
5.25	0.55	112-131	6.0	"	"	"	"	"	

NOTES: (1) Total charge discharge time for 2.9 KV ≈ 9 seconds
Total charge discharge time for 4.1 KV ≈13 seconds

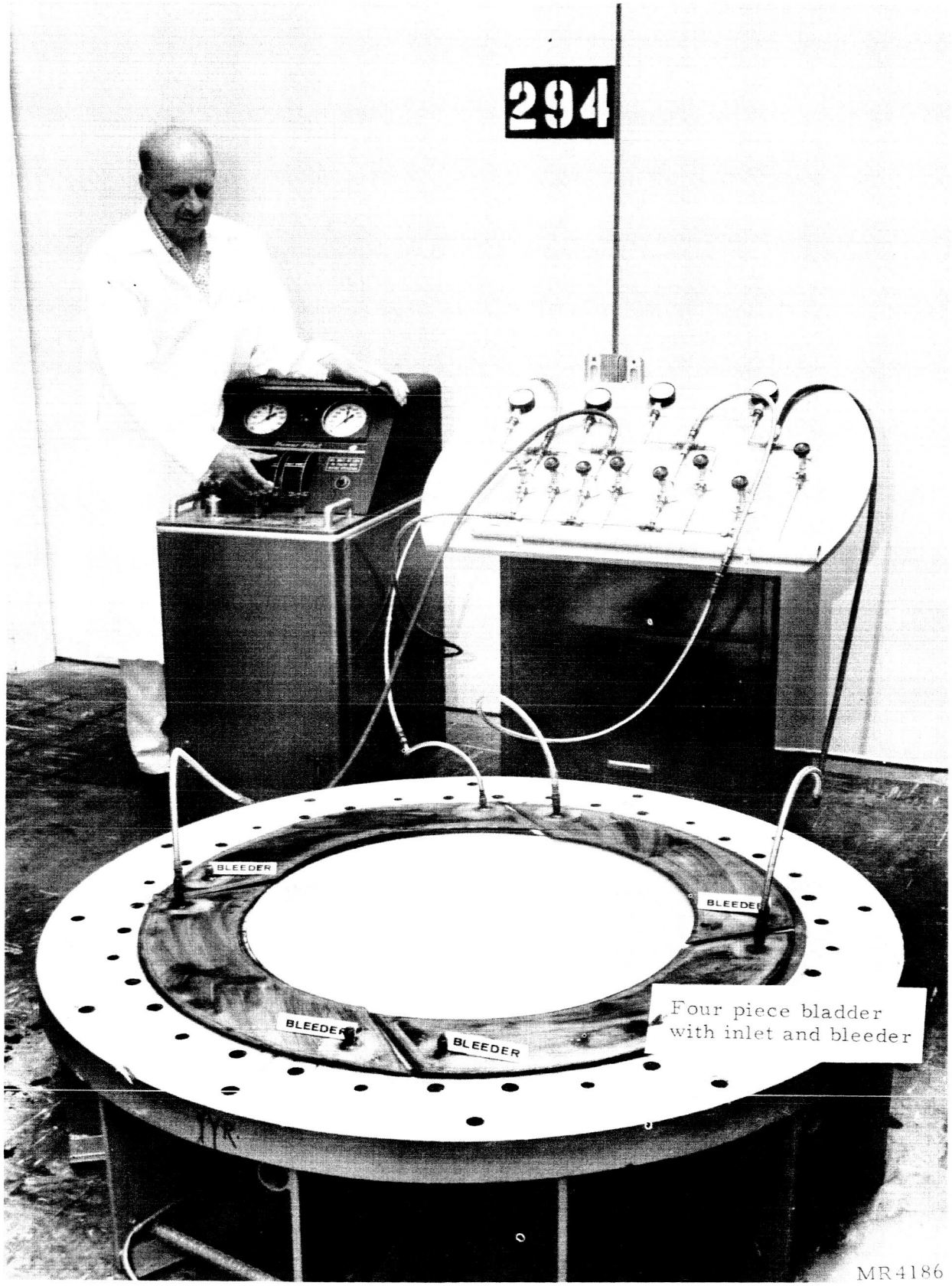
(2) After shot #34, a flash was observed and the apparatus inspected. The coil lead had sheared off and the aluminum spacer had loosened from the steel head filled cylinder. To corrent this, the aluminum spacer was spot welded (rather than bolted as the bolts had stripped loose) and the coil lead re-connected.

(3) Discharge audibly different - 2 of the 3 rubber cushions had jarred loose. Also the steel cylinder loosened from the lid mounting - the cylinder was spot welded to the lid.

*See Figure 9

28" DOME SPECIMEN 61 - FORMED WITH WAVE GENERATOR

FIGURE 8



COMPLETE SYSTEM OF SELECTIVE FLANGE-BLADDER CONTROL SHOWN IN POSITION ON THE PLASTIC DIE

FIGURE 9